Particulate Matter and Health Effects in North Idaho: An Evaluation of Air Monitoring and Health Insurance Data

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Abstract

The Idaho Department of Health and Welfare, Bureau of Community and Environmental Health conducted a study of particulate matter (PM) levels and subsequent effects on health care encounters of cardiovascular and pulmonary illnesses in north Idaho. Health insurance data were collected from Blue Cross of Idaho, Idaho Medicaid, and Regence Blue Shield of Idaho. Since Medicare data could not be obtained, only individuals 64 years of age and younger were included. Data linkage was performed using Link Plus software to link the data from the three sources and de-duplicate records. Hourly ambient air monitoring data were provided by the Idaho Department of Environmental Quality. The time-series analysis used Poisson regression in generalized additive models on daily health effects counts with lagged air quality data and controlled for day of week and smoothed functions of time and temperature. Results show that increases of 10 $\mu g/m^3$ in PM2.5 (particle size less than 2.5 micrometers in diameter) and of 50 $\mu g/m^3$ in PM10 (particle size less than 10 micrometers in diameter) were associated with an increase of 11% and 33% respectively in acute stroke health care encounters; increases of 50 $\mu g/m^3$ in PM10 were found to be associated with increases in health care encounters for both acute lower respiratory illnesses and acute upper respiratory illnesses by 13% and 10% respectively; and, increases of 50 $\mu g/m^3$ in PM10 were associated with a 27 % increase in chronic cardiac illness health care encounters. This study is unique from most PM studies because it obtained data from insurers resulting in a more robust collection of health data than studies that normally rely on hospital admission, emergency room use, or death certificate data, and this study used hourly PM monitoring data which provides for a more accurate exposure metric than studies that only have access to environmental data that is collected less frequently.

Introduction

Particulate matter (PM) is a complex mixture of fine solids such as dirt, soil dust, pollens, molds, ashes, soot, and aerosols that are formed in the atmosphere from gaseous combustion by-products such as volatile organic compounds, sulfur dioxide, and nitrogen oxides. To date, there have been over 2000 peer-reviewed articles on PM pollution and its effects on pulmonary and cardiovascular health. These studies show that PM pollution is especially harmful to people with lung disease, such as asthma and chronic obstructive pulmonary disease (COPD), which includes chronic bronchitis and emphysema. However, even though the relative effects of PM air pollution are greater for respiratory deaths than for cardiovascular deaths, the number of deaths attributable to PM is much larger for cardiovascular than for respiratory reasons due to the higher prevalence of cardiovascular disease in the general population (Bai et al.). Further, many studies are now finding adverse health effects when PM levels are at or below the air quality standards set by the U.S. Environmental Protection Agency (EPA).

According to the EPA, the published scientific studies have linked PM pollution exposure to a variety of problems, including:

- increased respiratory symptoms, such as irritation of the airways, coughing, or difficulty breathing;
- decreased lung function;
- aggravated asthma;
- development of chronic bronchitis;
- irregular heartbeat;
- nonfatal heart attacks; and
- premature death in people with heart or lung disease.

In 2004, the Idaho Department of Health and Welfare's Bureau of Community and Environmental Health (BCEH) received a grant from EPA to study the possible relationship between agricultural burning on the Rathdrum Prairie and health effects. Specifically, the proposal was to describe the pattern and incidence of asthma and other respiratory diseases along with cardiopulmonary events during the burn season, and to describe the pattern and prevalence of emergency room admissions, in-patient admissions, and ambulatory care utilization during the burn season. However, due to the limited years of health data available, BCEH had to modify its proposal to look at air pollution in general and its possible effects on respiratory and cardiovascular health in north Idaho.

Originally the goal of the study was to use health data from January 2000 through December 2004. The goal was changed because quality controlled health effects data were not available from one health insurance company prior to October 2002. This lack of data meant that analysis had to be limited to the dates October 1, 2002 through December 31, 2004. There were only two burn seasons on the Rathdrum Prairie during this time period. The burn days were determined by the Idaho State Department of Agriculture (ISDA) with assistance from the Idaho Department of Environmental Quality (IDEQ). Under the Idaho State Crop Residue Disposal Agricultural Smoke Management Program rules, ISDA and IDEQ are required to limit the impact of smoke from field burning on local communities by using meteorological and air quality data to determine days when the smoke will rise and dissipate rapidly. During the 2003 and 2004 burn seasons there was a total of 14 days when field burning occurred on the Rathdrum Prairie. These few number of burn days along with the controls placed on field burning precluded a study examining the possible association between field burning and health effects. As an alternative, BCEH decided to look at the impact of PM levels on health in north Idaho.

Methods

To conduct this study, BCEH obtained environmental data and health data. The environmental data included air monitoring data that were requested from IDEQ. IDEQ collects air quality data at several locations in north Idaho in order to fulfill their responsibility for protecting public health against the adverse impacts of air pollution. IDEQ provided data from their north Idaho monitoring stations in Post Falls, Coeur d'Alene, and Sandpoint (see Figure 1.) IDEQ also provided data from their seasonal monitors that operate at locations on the Rathdrum Prairie during the agricultural field burning season.

BCEH requested air monitoring data from January 1, 2000 through December 31, 2004 from IDEQ stations in north Idaho. IDEQ provided PM10 data collected by a Tapered Elemental Oscillating Microbalance (TEOM) for Sandpoint. IDEQ did not conduct daily PM2.5 monitoring in the Sandpoint area, thus all PM2.5 analyses in the report are based on the data from Coeur d'Alene and Post Falls. The PM10 data for Coeur d'Alene were collected by a TEOM located at Lakes Middle School. PM2.5 data were collected by TEOMs at Lake Middle School in Coeur d'Alene and in Post Falls. Since the Coeur d'Alene and the Post Falls areas are considered to be in the same airshed, a daily arithmetic average for PM2.5 was calculated using data from the two sites.

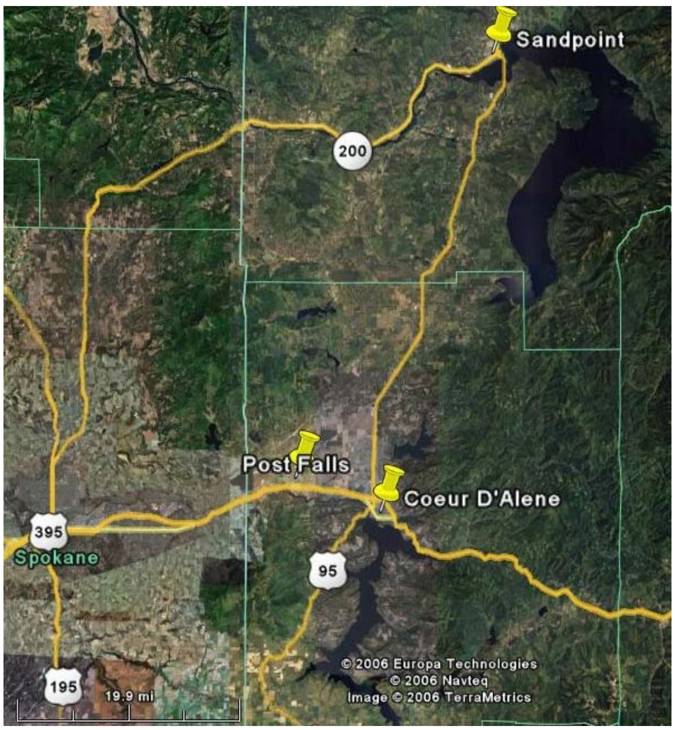

Figure 1. Air Monitoring Stations

To determine the average air quality for the region, the study took the mean daily PM10 data from the Coeur d'Alene/Post Falls area and the mean daily PM10 data from the Sandpoint area and calculated a weighted mean PM10 value. Coeur d'Alene was weighted 0.7 and Sandpoint was weighted 0.3. The weights were selected to reflect the population sizes for the two initial analysis areas and allow the exposures to be considered as population-based for the overall area.

Other environmental data included meteorological data which were obtained from the National Climactic Data Center (http://www.ncdc.noaa.gov) and included the daily maximum and minimum temperatures for each study day.

Health care encounter data were requested from Blue Cross of Idaho, Regence Blue Shield of Idaho, Idaho Medicaid, and QUALIS Health (Medicare) for the time period January 1, 2000 - December 31, 2004. Data were received for the period requested from Idaho Medicaid and Blue Cross of Idaho. Regence Blue Shield of Idaho was able to provide data for the period October 1, 2002 – December 31, 2004. QUALIS did not provide any health data.

The International Classification of Diseases, 9th Revision (ICD-9) is a listing of diagnoses codes used by physicians for reporting diagnoses of patients. ICD-9 codes are used to provide a uniform language that can accurately designate primary and secondary diagnoses and provide reliable, consistent communication on claim forms. All health care encounter data (outpatient, inpatient, emergency room, etc.) with ICD-9 Codes in any of up to 6 diagnosis fields were queried by each data source. The ICD-9 Codes queried are included in Table 1.

Table 1. ICD-9 Codes

ICD-9 Code	Diagnoses
410.00 - 410.92	Ischemic Heart Disease
411.xx	Other Acute/Subacute Ischemic Heart Disease
412.xx	Old Myocardial Infarction
413.00 - 413.99	Angina
414.xx	Other Forms Of Chronic Ischemic Heart Disease
415.xx	Acute Pulmonary Heart Disease
416.xx	Chronic Pulmonary Heart Disease
417.xx	Other Diseases Of Pulmonary Circulation
425.0x - 425.9x	Cardiomyopathy
426.0x - 426.9x	Conduction Disorders
427.0x - 427.9x	Cardiac Dysrhythymias
428.00 - 428.93	Coronary Health Failure
429.xx	Ill-Defined Descriptions And Complications Of Heart Disease
430.xx - 438.9x	Cerebral Hemorrhage And Infarction
440.xx	Atherosclerosis
441.xx	Aortic Aneurysm
442.xx	Other Aneurysm
443.xx	Other Peripheral Vascular Disease
444.xx	Arterial Embolism And Thrombosis
445.xx	Atheroembolism
446.xx	Polyarteritis Nodosa And Allied Conditions
447.xx	Other Disorders Of Arteries And Arterioles
448.xx	Disease Of Capillaries
461.xx	Acute Sinusitis
462.xx	Acute Pharyngitis
463.xx	Acute Tonsillitis
464.xx	Acute Laryngitis And Tracheitis
465.xx	Acute Upper Respiratory Infections Of Multiple Or Unspecified Sites
466.0x - 466.1x	Acute Bronchitis And Bronchiolitis
472.xx	Chronic Pharyngitis And Nasopharyngitis
473.xx	Chronic Sinusitis
476.xx	Chronic Laryngitis And Laryngotracheitis
478.xx	Other Diseases Of Upper Respiratory Tract
480.xx	Viral Pneumonia
481.xx	Pnemococcal Pneumonia
482.xx	Other Pneumonia
483.xx	Mycoplasma Pneumonia
485.xx	Bronchopneumonia, Origin Unspecified

ICD-9 Code	Diagnoses
486.xx	Pneumonia, Origin Unspecified
490.xx	Bronchitis, Not Specified As Acute Or Chronic
491.xx	Chronic Bronchitis
492.0x - 492.8x	Emphysema
493.00 - 493.92	Asthma
494.xx	Bronchiectasis
495.xx	Extrinsic Allergic Alveolitis
496.xx	Chronic Airway Obstruction, Not Elsewhere Classified
786.xx	Symptoms Involving Respiratory System And Other Chest Symptoms

Additional fields included date of service and personal identifiers. The personal identifiers were used to link patients across and within datasets. A study identifier not traceable to source records was used in a de-identified incident-level file for statistical analysis.

Health Effects Data Linkage

Health care encounter data were received from Idaho Medicaid, Regence Blue Shield of Idaho, and Blue Cross of Idaho. In order to match individuals who may have been insured by two or more of the carriers, a data linkage was performed. Regence Blue Shield of Idaho and Blue Cross of Idaho data sometimes had more than one patient identifier for the same person because they may have been assigned a new identifier when they changed employers or plans. These records were consolidated prior to the linkage. Link Plus software, a probabilistic record linkage program developed by the Centers for Disease Control and Prevention, was used to link the data from the three sources. Duplicate records in the incident-level data (i.e. same person, date of service, and ICD-9) were deleted.

ICD-9 codes in any of up to six different ICD-9 fields were queried for index diagnoses. Incidents of asthma, COPD, acute lower respiratory tract infection, acute upper respiratory tract infection, chronic upper respiratory tract infection, acute cardiac event, chronic cardiac event, conduction disorder and acute thrombolytic event were coded separately. For the study, a health care encounter (a case) was defined as an individual's diagnosis with one or more of the ICD-9 codes listed in Table 1. Since an individual could be seen multiple times over a series of days for the same initial health encounter, it was necessary to use a counting rule to avoid multiple counts for the illness episode. To avoid over-counting health encounters for an individual, only the index diagnosis was counted per individual in any three-day period of time. If the same diagnosis occurred four or more days after the initial health care encounter, it was counted as a separate health care encounter.

For the study area, the number of each of the health outcomes was counted by day, sex, and five-year age group. This dataset of counts was "filled out" with zero counts such that each combination of day, sex, and age group was populated with zero or the non-zero count from the health outcomes data. Due to the availability of health outcomes data, the study was limited to October 1, 2002 – December 31, 2004. Also, because Medicare data were not included in the study, only cases among persons 64 years of age or younger were included in the analysis.

Mid-year population estimates were obtained by county, age, and sex from the National Center for Health Statistics (2005). Daily estimates of person-years of exposure were calculated as 1/365 times the annual population estimate for each of the study years.

Statistical Analysis

Time-series analyses were conducted to evaluate the relationships between daily changes in PM levels and daily counts of health effects. The analysis was completed using SAS® statistical software. SAS® Proc GAM (generalized additive model) was used to test the effects of changes in same day and lagged air quality on daily health effect counts adjusting for time, meteorology(including minimum and maximum temperatures), and day of week. Daily health effect counts were modeled as a Poisson random variable using a log link function. Time and weather variables were smoothed using cubic splines.

Spline functions of the variables were used to control for long-term and seasonal trends. Models were run with six degrees of freedom per year for the time variable, two degrees of freedom for each of the weather variables, and using generalized cross validation to choose the degrees of freedom. For the GAM analysis, daily counts were summed over sex and age group for each health outcome.

For each GAM model of interest, a sensitivity analysis was conducted in SAS PROC GENMOD to evaluate the effects of the parameterization of time and weather. For the sensitivity analyses, daily health effect counts were modeled as a Poisson random variable using a log link and the log of the daily person years as an offset variable. Four parameterizations of time were utilized: linear, cubic, cubic with four knots per year, and cubic with 12 knots per year. Square and cubic terms for the minimum and maximum temperature variables were utilized for each of the sensitivity analysis models.

To test the models, sensitivity analysis were run for all significant findings. The sensitivity analyses showed that model results were generally not sensitive to the parameterizations chosen for time and weather in the main GAM models. Effect size estimates from the sensitivity analyses were consistent with those from the main GAM models.

Results

To investigate the possible relationship between PM and illnesses, the study looked at health effects associated with daily mean concentrations of PM2.5 and PM10 (see Table 2). The analysis using PM2.5 found that increases in PM2.5 were associated with an increase in acute stroke health care encounters. Using a lag time of four days, an increase of 10 $\mu g/m^3$ in the daily mean PM2.5 was associated with an 11% increase in the number of acute stroke health care encounters (p value = 0.017). There were no significant findings using lag times of zero, one, two, or three days.

Using a lag time of one day, the study found that an increase of 50 $\mu g/m^3$ in the daily mean PM10 level was associated with a 13% increase in acute lower respiratory health care encounters (p value = 0.0006) and a 10% increase in acute upper respiratory health care encounters (p value = 0.0075).

An increase of 50 $\mu g/m^3$ in the mean daily PM10 level along with a three-day lag time was associated with a 27% increase (p value = 0.0003) in chronic cardiac health care encounters. Using a lag time of four days, increases in PM10 levels were associated with a 33% increase in acute stroke health care encounters (p value = 0.023).

Table 2. Increases in Daily Counts of Health Effects Associated with Increases of PM2.5[1] and PM10[2] in Individuals 64 Years of Age or Younger

PM Size	Health Effects	Lag Time	Percent Increase	95% Lower CI	95% Upper CI
PM2.5	Acute Stroke	4 Days	10.5	1.8	20.0
PM10	Acute Lower Respiratory	1 Day	13.1	5.4	21.3
PM10	Acute Upper Respiratory	1 Day	10.4	2.7	18.7
PM10	Chronic Cardiac	3 Days	26.7	11.7	43.8
PM10	Acute Stroke	4 Days	32.7	4.1	69.2

[1]The increase in PM2.5 was 10 $\mu g/m^3$ in any 24-hour period.
[2]The increase in PM10 was 50 $\mu g/m^3$ in any 24-hour period.

For an analysis of the number of health care encounters by month and the monthly and yearly crude illness rates see Appendix A.

Discussion

Environmental pollutants are rapidly being recognized as important and independent risk factors for several diseases such as asthma, chronic obstructive pulmonary disease, lung cancer, atherosclerosis, ischemic heart disease, and stroke (Bai et al.). Many studies researching PM's impact on health have used emergency room data, hospital admission data, and death certificates. This study differs from most because it used health insurance industry data rather than emergency room use data, hospital admission data, or death certificates for health effects data. Having data from health insurance companies increases the number of cases used in the analysis by including those individuals who use an emergency room, as well as those who see a private physician or go to a clinic. However, by using insurance data, the study did not include the uninsured which is estimated to be 24% in this region of Idaho (BRFSS), those who may be insured by smaller insurance companies, those individuals whose employers are self-insured, and those who were 65 or older.

The results of a time-series analysis showed increases in PM2.5 and PM10 resulted in increased daily health care encounters for cardiopulmonary diseases, including upper and lower respiratory illnesses, chronic cardiac, and acute stoke. These results parallel previous findings of earlier studies. While many studies, such as Sheppard et al. and Peters et al., have linked ambient air pollution to increases in asthma morbidity, this study did not result in any significant findings. It is not clear why there were no significant findings in this study for asthma though the differences in methods used may have some bearing on the results. Lin et al. found a significant association using a time-series study that averaged PM levels over 5-6 days instead of using daily means and lag intervals as our study did. Also, some studies' findings suggest that the specific constituents of air pollution, such as sulfur dioxide and ozone, may play a bigger role in inducing or exacerbating asthma than the amount of PM. Since we did not have the data for the constituents of the air monitored, we could not do an analysis to determine if specific constituents of air pollution might be associated with asthma rates in north Idaho.

The increase in acute stroke health care encounters associated with increases in air pollution is consistent with some recent studies, including Chan et al. The Chan study found in single-pollutant models PM 2.5 and PM 10 lagged three days were significantly associated with increasing emergency admissions for cerebrovascular diseases. Our study's findings that the rate of increase (33%) associated with an increase of 50 $\mu g/m^3$ in PM10 with a lag of four days is difficult to compare with many other studies due to the fact that most studies investigating the relationship between PM and acute stroke use mortality data, not morbidity data. However, a British study by Maheswaran et al. used modeled PM10 data overlaid on census districts. Looking at the rate ratios for stroke associated with quintile ranges of PM, the study found that the risk for hospitalization for stroke was 13% higher in the highest relative to the lowest quintile range of PM10 and that stroke mortality was 33% higher in the highest relative to the lowest quintile range. It should be noted that although our results are high, it is possible that our results for acute stroke may be underestimated due to the exclusion of individuals who were 65 or older.

The association between PM and respiratory disease is well documented in the medical literature. While our study's analysis found that the association between both acute lower respiratory (1 day lag/13% increase for 50 $\mu g/m^3$ increase in PM10) and acute upper respiratory (1 day lag/10% increase for 50 $\mu g/m^3$ increase in PM10) health care encounters and PM10 were significant, it did not find any significance between chronic respiratory health encounters and mean daily PM10 or PM2.5. Other studies (Peel et al.; Hagen et al.; Atkinson et al.) have found a significant positive association between emergency room visits and hospital admissions for respiratory disease and PM10. A study by Ulirsch of the PM values in Pocatello, Idaho, found that with an increase of 50 $\mu g/m^3$ in PM10 that there was an increase in visits for respiratory illness of 7.1% for all ages combined. The increase for those 65 and older was 15.4%.

In a study of children three years old and younger in Vancouver, British Columbia, Yang et al., used logistic regression to estimate the associations between ambient concentrations of PM and first hospitalization. The adjusted odds ratios for first respiratory hospitalization associated with mean and maximal PM10 and PM2.5 with a lag of three days were 1.12 (95% CI: 0.98, 1.28) and 1.13 (95% CI: 1.00, 1.27) respectively. Our study differs from the Yang study since Yang's study found significance with only one lag day, included a broad array of respiratory illnesses, and only looked at children three years of age and younger.

Our study did not find any positive association between PM levels and acute cardiac health care encounters; however, it did find that chronic cardiac health care encounters were positively associated with increases in PM10 levels. Specifically, this study found that an increase of 50 $\mu g/m^3$ in PM10 levels with a three-day lag period was associated with a 27% increase in chronic cardiac illness health care encounters. A similar study by Zanobetti et al. examined the association between PM10 and hospital admissions for heart and lung disease in ten U.S. cities. Zanobetti's study found that when PM10 increased 10 $\mu g/m^3$ there was an associated 1.27% increase in cardiovascular disease admissions. The major difference in the two studies is that the sole source of medical data in the Zanobetti study was Medicare data and covered only those 65 years of age and older. Our study had a larger data pool that included visits to hospitals, emergency rooms, private offices, and clinics. Also, our study excluded those 65 of age and older.

Study limitations

This study has several limitations including the use of regional air monitoring results, lack of Medicare data, and not being able to include the uninsured.

In most time-series studies of PM and health effects there is the issue of the appropriateness of using regional ambient air monitoring data. Regional ambient air monitoring data in north Idaho is collected at several locations. For our study we took the air monitoring data from two adjacent geographic areas and used those measures to arrive at a mean daily exposure of PM for all of the population in the study area. The area between Post Falls/Coeur d'Alene and Sandpoint is large and ambient PM levels may differ in the area separating the two population centers. Also, while we used ambient outdoor PM levels, these levels may differ from PM levels indoors where individuals spend most of their time (e.g. homes, schools, workplace). Given this, using outdoor regional ambient air monitoring data as a measure for personal exposures may overestimate or underestimate individual exposures. However, it should be noted that Zeger et al. suggests that using regional monitors for measuring air pollution impacts in time-series studies is likely to bias the results towards the null (i.e. strength of associations will be decreased).

Attempts were made to collect Medicare data, but the substantial cost associated with purchasing the data precluded its use. Due to this factor, the study had to exclude all individuals 65 and older. Other health studies of PM show that those 65 and older are at more risk from many health effects of PM so our analyses may have underestimated the effect of PM on cardiovascular and pulmonary disease.

By relying on health insurance companies' data the study excluded the uninsured in the study area which is estimated to be 24% of the adults aged 18-64. Being able to include the uninsured may have modified our findings somewhat since other studies have shown that individuals with a low socioeconomic status are more likely to suffer poor health.

Strengths

Though there are some limitations for this study, overall the study's design and data are fundamentally strong. The main strengths are the high quality health and environmental data used for the analysis.

Most studies of PM rely on hospital admission, emergency room use, or death certificate data; however, this study was able to acquire health insurance data which meant that a much larger number of individuals were included in the analysis than would have been had we used only hospital discharge data, emergency room data, or death certificates. This larger number of individuals used in the analysis translates into having better confidence in the findings.

This study was able to utilize hourly ambient air monitoring data. Other studies have relied on air monitoring data that is collected every other day or once every three days. By having hourly data, there is the ability to look at PM levels each hour and determine if any hourly measurement may be incorrect by comparing a level to levels measured the hour previous and the hour following. Twenty-four hour averages and measures made only once every three days do not allow for the quality control measures need to ensure a higher confidence in the environmental data. Also, hourly data provides a better representation of exposure than measures taken less frequently.

Conclusion

This study found that increases in PM levels in north Idaho are significantly associated with increases in the numbers of health care visits for upper and lower respiratory illnesses, chronic cardiac illnesses, and acute stroke. These findings are in line with previous studies of the impact of PM on pulmonary and cardiovascular health. Though the study was not able to specifically address the possible impact of field burning on health effects in north Idaho, it is well understood that agricultural burning contributes to PM. Because of the strong associations between elevated PM levels and increased health effects found in this study, continued efforts to reduce the impact of field burning and other anthropogenic sources of PM, such as urban sprawl, should be pursued in north Idaho in order to reduce air pollution related illnesses and to protect public health.

Studies have found that sensitive populations, such as the elderly, may suffer more health effects when PM levels are elevated. Since Medicare data were only available at a significant cost, this study was not able to include the population of residents who were 65 years of age and older. This exclusion of a sensitive population means that the study's results may underestimate the associations found between PM levels and health care encounters. It is recommended that any future studies should include those 65 years of age and older.

Appendix A: Health Care Encounters and Crude Illness Rates

As part of the deliverables for the grant, incidence rates of illnesses were calculated. Table 3 shows the number of health care encounters for the months during the study period. The counts were compiled from the three health insurers and only include individuals who were less than 65 years of age at the time of the medical visit.

Table 3. Number of Health Care Encounters by Month

Month and Year	Acute Lower Respiratory	Acute Upper Respiratory	Chronic Cardiac	Acute Stroke
October 2002	1532	1123	709	291
November 2002	1332	1140	609	279
December 2002	1541	1278	712	342
January 2003	1567	1230	711	349
February 2003	1969	1314	684	320
March 2003	2053	1435	724	353
April 2003	1385	1071	737	320
May 2003	1182	1052	785	285
June 2003	760	754	706	295
July 2003	610	697	750	291
August 2003	608	622	688	315
September 2003	1019	899	780	303
October 2003	1241	1099	871	269
November 2003	1555	1285	741	211
December 2003	1956	1323	833	267
January 2004	1213	1028	860	241
February 2004	1724	1166	799	229
March 2004	1758	1300	935	284
April 2004	1135	975	925	228
May 2004	1045	912	842	240
June 2004	823	859	829	251
July 2004	607	707	906	262
August 2004	572	635	840	206
September 2004	1083	856	895	231
October 2004	1290	974	840	197
November 2004	1467	1217	839	218
December 2004	1342	1128	818	210

For the years with complete medical data from the three insurers, we calculated crude rates of health care encounters for specific diagnoses (see Table 4). Rates were higher for asthma and chronic cardiac in 2004 as compared to 2003, but lower for chronic upper respiratory, acute upper respiratory, acute lower respiratory and acute stroke.

Table 4. Crude Illness Rates by Year*

	Asthma	Chronic Upper Respiratory	Acute Upper Respiratory	Acute Lower Respiratory	Chronic Cardiac	Acute Stroke
2003	4161.9	954.3	7671.3	9562.1	5395.3	2144.7
2004	4429.8	891.3	6802.6	8144.3	5968.0	1616.4

* per 100,000 individuals

Table 5 shows the crude illness rates on a monthly basis. Using a monthly average for the two, full years of the study, the four months with the highest rates of asthma illnesses were February, November, October, and March. The difference between the highest and the lowest monthly average asthma rate was 1948.0 with February having the highest rate and July having the lowest rate. For chronic upper respiratory illnesses, the difference between the highest and the lowest monthly average rate was a rate of 651.7, with February having the highest rate and August having the lowest rate. Acute upper respiratory illnesses had the highest rate in March and the lowest rate in August. The difference between the two rates was 5134.0. The rate of acute lower respiratory illnesses was highest in February and lowest in August, with a difference of 9876.4. The rate of chronic cardiac illnesses was highest in September and lowest in August, with a difference of 705.3. Finally, the rate of acute stroke illnesses was highest in March and lowest in November, with a difference of 676.1.

Table 5. Crude Illness Rates by Month and Year*

	Asthma		Chronic Upper Respiratory		Acute Upper Respiratory		Acute Lower Respiratory		Chronic Cardiac		Acute Stroke	
	2003	**2004**	**2003**	**2004**	**2003**	**2004**	**2003**	**2004**	**2003**	**2004**	**2003**	**2004**
January	4555.0	3969.8	1029.5	832.7	8672.9	7011.9	11049.1	8273.8	5013.4	5866.0	2460.9	1643.9
February	5347.5	5264.4	1319.3	1122.9	10257.9	8501.7	15371.2	12570.3	5339.7	5825.8	2498.1	1669.7
March	4244.8	5129.4	1269.2	1145.9	10118.4	8867.2	14476.0	11991.2	5105.0	6377.6	2489.1	1937.2
April	4131.3	4567.3	1202.2	923.3	7803.5	6872.1	10091.4	7999.8	5369.9	6519.7	2331.6	1607.0
May	4082.6	4379.1	1008.3	825.3	7417.8	6220.7	8334.4	7128.0	5535.1	5743.2	2009.6	1637.0
June	3504.6	4144.4	786.9	845.8	5493.8	6054.5	5537.5	5800.8	5144.0	5843.1	2149.4	1769.1
July	3236.5	3478.7	705.1	668.5	4914.6	4822.4	4301.2	4140.3	5288.4	6179.8	2051.9	1787.1
August	3173.0	3621.9	620.5	518.4	4385.8	4331.3	4287.1	3901.6	4851.2	5730.0	2221.1	1405.1
September	4116.7	4468.6	845.2	888.1	6550.3	6033.4	7424.6	7633.3	5683.2	6308.3	2207.7	1628.2
October	4639.7	4754.2	1085.9	1030.0	7749.2	6643.6	8750.5	8799.0	6141.5	5729.6	1896.8	1343.7
November	4495.6	5110.0	670.3	1015.0	9362.7	8577.8	11330.0	10339.9	5399.1	5913.5	1537.4	1536.5
December	4407.0	4269.9	909.6	879.9	9328.7	7694.0	13792.0	9153.7	5873.6	5579.5	1882.7	1432.4

* per 100,000 individuals

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